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BAYER LEVERKUSEN (GERMANY)
Department for Plant Protection

Control of Beet Moth on Sets in Spain, 1955

by Dr. O. Günther, Leon, Spain

The propagation area of the beet moth *(Phthorimaea ocellatella* Boyd), as mentioned previously in scientific literature, covers the whole of the Iberian peninsula, and consequently the beet growing region of North Spain, too. During very dry years, the pest is capable of inflicting very serious damage particularly in districts where there are no irrigitation systems. Trial controls carried out in the past were not very successful. As yet, there are no publications available reporting on trial controls having been conducted with new synthetic insecticides and systemic preparations.

In this paper, a brief description is given of the development of the pest and the injury it causes, based on the author's own observations (1) and observations of Menozzi (2). Reference is also made to the pest in the handbook of Sorauer (3).

The pest occurs in North Africa, Asia Minor, South Europe, France and England. The moth makes its appearance in May, and lays its eggs either in or close to the young beets. From then onwards until October and November, larvae of the moth are to be found continuously in the beet tops which leads to the assumption that there are several generations during the course of a year. The larvae bore short galleries in the stalks of the young leaves, remain concealed between the youngest leaves which have just developed, and cover the entire heart of the plant with their sticky excrement. As long as there is plenty of rainfall and the beets continue to grow vigorously, the injuries caused by the feeding activities of the larvae do not constitute really serious damage. However, as soon as the dry period commences in Summer and the growth of the leaves becomes weaker, the injuries may become extremely grave. Only the outer leaves are spared from attack in serious infestations. The entire heart is destroyed, and the plant dies sooner or later. The damage is reduced by favourable growing conditions and irrigation. Often, however, the damage caused represents a great percentage of the probable yield of tops, beet weight and sugar content.

Spraying and dusting tests carried out in the past have produced more or less negative results because on the one hand the larvae are inaccessible to the preparation in their galleries or they conceal themselves most effectively under their excrement, and on the other hand they are able to lower themselves to the ground very rapidly on a thread.

The pest not only occurs in stands of beets grown for factory processing but also causes similar damage in fields of sets. In view of the fact that the climate in Spain is warm enough for the sets to be left in the soil during the

Winter months, and because the lavae are able to overwinter without suffering any great losses in population due to the relatively mild weather, a control at the right time is very important.

In 1942, Menozzi recommended that the sets should be immersed by their tops in a 0·5 % solution of nicotine sulphate before bedding out and after the leaves have been cropped. Judging from the biology of the moth larvae, it would appear that a control method of this description does not have much prospect of success.

Our tests were conducted in a district where the climate is so mild that the sets can be transplanted in Autumn. The sets, therefore, are not clamped, nor are they left in the nursery during the Winter but are transplanted into the beet field in November. Naturally, the field has to be prepared in good time. We believe November to be a most favourable month for transplanting because an opportunity is then given for selecting the seriously injured sets on which the heart leaves have hardly developed or probably not at all. Of course, these plants might sprout again in Spring but the majority would die after they have produced a few new leaves. After the plants have been selected, the leaf stalks of those left over for transplanting are cut down to a length of 1 to 2 cm, and then treated. Following the treatment which is described below, we leave the plants to stand in heaps for one or two days so that the insecticide can continue to act without evaporating, and then we transplant the sets in the usual manner. As the weather remains mild well into December, the first small leaves are able to develop before the winter conditions set in, which means that we have the guarantee that the plants have taken root before the first frost appears. In fact, in this region the frost is seldom so severe that it is anything more than a night-frost. During the daytime, the temperature remains above 0 ° C all through the Winter.

Past experience has shown our control method to be fully effective with the result that the transplanted beets remain more or less completely free from moth larvae. Consequently the plant, after it has grown up in Autumn, can overwinter without interference, and will then make rapid development in Spring.

Our tests were conducted with "Systox", liquid and powder formulations of "Folidol-E 605", and finally with "Metasystox". Details of the concentrations used and the methods of application are given below:

A. Spraying of the sets in the field.
B. Immersion of the lifted sets by their tops in the solution.
C. Immersion of the roots in the solution.

Concentrations:
For A: 0·1 % "Systox", 0·2 % "Metasystox", 0·5 % "Folidol-E 605",
For B: 0·5 % "Systox", 1·0 % "Metasystox", 1·0 % "Folidol-E 605",
For C: as for B.

The results of the tests are compiled in the following table.

A: It was observed that for all three preparations applied, there was a high knock-down of larvae only when they were directly hit by the liquid. However, as a large number were able to escape quickly from the effective range of the spray wash, this method did not give us sufficient guarantee for a 100 % eradication of the larvae. A check on the residual effect after periods

Trial Control against Beet Moth in Spain, 1955

Test	Type of treatment	Preparation and concentration expressed in %	No. of plants	No. of larvae before treatment	Kills						Remarks
					No. of larvae after			in % after			
					2 hrs.	1 day	8 days	2 hrs.	1 day	8 days	
A	Spraying with the hand sprayer	"Systox" 0·1	200	460	14	42	46	3	9	10	600 l liquid/ha
		"Metasystox" 0·2	200	531	21	37	43	4	7	8	
		"Folidol-E 605" 0·2	200	310	6	31	32	2	10	10	
		untreated	200	535	0	0	1	0	0	0	
B	Immersion of beet tops	"Systox" 0·5	200	690	614	683	683	89	99	99	100 l liquid/ha
		"Metasystox" 1·0	200	569	410	552	558	72	97	98	
		"Folidol-E 605" 1·0	200	611	458	546	546	75	92	92	
		untreated	200	621	0	0	0	0	0	0	
C	Immersion of beet roots	"Systox" 0·5	200	352	0	18	35	0	5	10	50 l liquid/ha
		"Metasystox" 1·0	200	371	0	15	41	0	4	11	
		"Folidol-E 605" 1·0	200	401	0	0	0	0	0	0	
		untreated	200	386	0	0	0	0	0	0	

of several hours to 8 days, showed that this method cannot be applied for practical purposes.

B: The immersion of the beet tops in the insecticidal solution proved to be a complete success. Even "Folidol-E 605" in powder form gave good results by this method. The check showed that the plants remained free from larvae for periods of up to eight days following the treatment. Consequently, this method was introduced on a large scale, and recommended to farmers.

C: Method "C" was applied to complete the test series. Although it did not produce such good results as method "B", it proved to be much more effective than spraying. We did not continue using it because it offers no advantages in the field. The tops can be immersed much more easily, and relatively less liquid is used. The beets were lifted from the beds, and knocked to remove any soil clinging to them. Then the top was cut with a knife to a length of 1 to 2 cm so that only the bases of the outer and the smallest inner leaves were left. The top was then dipped in the liquid. Afterwards, the sets were left in heaps for 1 to 2 days so that the preparation could penetrate into the beet without evaporating. Most of the larvae were killed during these two days.

With method "B", we applied 100 litres of liquid to 20,000 plants (70 × 70 cm spacing, giving an area of 1 hectare). "Systox", at a concentration of 0·5 %, was therefore applied at a rate of 500 g of preparation per hectare. Compared with the success of the control, the costs are most negligible particularly when it is considered that aphids were also killed at the same time.

Summary

"Systox", "Metasystox" and "Folidol-E 605" produced excellent results against the mining larvae of the beet moth, *Phthorimaea ocellatella* Boyd.

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Methods of Applying Insecticides in Tropical Field Cultures

by Dr. Hasso von Eickstedt, Mexico

The consumption of insecticides in field cultures of warm regions is far greater than in areas of equal size in Europe. The vast cotton growing industry in the U. S. A. and in Central America is one of the greatest consumers of insecticides because the plantations in the wet tropics are treated up to thirty times per vegetation cycle with economic success. In fact, thirty-six applications of insecticide a year are by no means a rarity in Salvador.

With such a high consumption of insecticides in field cultures — in Mexico alone with its 1 million hectares of cotton fields, 100,000 tons of dust preparations are used annually — amounting to a sales value on the American continent of several hundred million US dollars a year, it is evident that by employing effective application methods not only will there be a considerable financial saving but also the success of the control and the yield will be much greater.

Therefore, in this paper an attempt will be made to give a survey of the most important types of equipment and their method of operation, which are used today for applying insecticides in the field cultures of the warm regions and the tropical zones. A brief reference will also be made to the particle sizes of dusts and spray droplets, and how they are influenced by warm climatic conditions.

1. Dusters

Portable dusters

Considering that field crops today are nearly always cultivated in rows, the crank duster has proved to be the most popular of the portable types because its continuous air blast gives a more even dust coverage of the plants than bellows dusters with intermittent dust discharge.

Crank dusters are often fitted with two nozzles, either to dust two rows at the same time or to treat one row of plants from two sides.

Engine-powered portable dusters

This type of duster, which can be regarded as an improvement on the manually operated crank duster, has gained considerable importance in recent years. There are knapsack dusters designed for operation by one person, which are sometimes found to be of disadvantage because of the additional weight and the vibration of the gasoline engine, whereas on the other hand, their air output is considerably greater than that of the manually operated dusters.

Engine-powered portable dusters with a motor output of 2 to 3 horsepower which gives a relatively good throw, are available designed for carrying by two operators, and are very popular. These types are carried like a stretcher by operators working in low plantations, while in cotton fields where the plants are at chest-height, they are mostly carried on the shoulder. In many cases they are only used for late treatments of cotton plants which have grown almost to the height of an average man. At the beginning of the vegetation period, tractor sprayers are more widely used because they are cheaper to operate than dusters. It is not until later when the tractors cannot be driven through the densely growing crops that growers revert to the use of portable dusters.

Tractor-mounted and tractor-drawn single outlet dusters

Dusters of a construction similar to that of the engine-powered portable types can be mounted at the rear of the tractor which is also fitted with a platform in order to carry several bags of dust. The blower is driven either by means of the power take-off shaft via belt and pulley or by a separate

gasoline engine. The largest tractor-drawn dusters fitted with lateral blast pipes are designed as trailers, and are coupled with a 12 to 28 H. P. gasoline engine. American designs with axial blowers are equipped with considerably more powerful generators.

Recently such types of engine-powered dusters have been fitted with additional atomizer installations. The air stream from the blower is used on these types to break up the spray liquid which is fed centrally into the blast pipe with hardly any pressure exerted on it, into fine droplets. The size of the produced droplets and the plant coverage are, however, far from being uniform for some of these types.

The duster types referred to last, naturally have a considerable throw which is of great advantage when plants have to be treated in an advanced stage of growth. On the other hand, the dust coverage given by these types fitted with horizontal blast pipes may be very uneven on the plants, and a large percentage of dust may be wasted due to drifting.

Consequently engine-powered dusters of this design should only be used when there is no wind and the sun is not shining, i. e. late evening or early morning, otherwise too much dust will be wasted.

Tractor-drawn or mounted multiple outlet dusters

In regions where the cotton does not grow to a height of more than 3 to 5 feet, the crop can be treated for a very long period with tractor-mounted dusters equipped with individual nozzles for row dusting.

The blower on these types is mostly driven by the power take-off shaft, and it is equipped with 6 or more tangential connections to which flexible hoses are fitted. These dust hoses, made of metal or rubber, are run out over the plant rows by means of a boom, and the dust is discharged onto the plants from above through a nozzle shaped in the form of a spoon or a fishtail.

Some dusters are also fitted with divided nozzles which discharge dust onto the rows from two sides, or with tube-like dust distributors equipped with fishtail nozzles directed downwards.

Naturally, the nozzles are adjustable to conform with the width of the rows and the height of the plants in order to treat different crops, if necessary.

The advantage of the multiple outlet dusters is that there is less drift of dust should the weather be windy at the time of the treatment because the dust is discharged between the plants from above, and consequently the plants prevent the dust from being blown away by the wind. An apparatus of this type is, therefore, not only economical in the consumption of insecticide but it can also be operated much longer during the day than the engine-powered dusters referred to earlier.

2. Sprayers

Following the introduction of modern insecticides and plant growth regulators for weed control, preparations which are applied at a rate of anything between 200 grammes and several kilogrammes of active substance per hectare,

the development of field sprayers and sprayer aircraft — the latter will be discussed in Section 3 — was revolutionized on a far greater scale than that of dusters.

The main issue was to reduce the volumes of water applied per acre, which in the past had been very high. As a result of the development of low volume nozzles, on the one hand, and the production of highly effective, emulsifiable insecticides, on the other hand, it was possible to reduce the former water consumption rate of 1000 litres per hectare when applying insecticides and plant growth regulators (herbicides) to less than 100 litres per hectare, and in certain cases even to approximately 20 litres per hectare (but not for fungicides).

With these spraying methods, generally known as low volume spraying, the quantities of active substance applied per acre remain the same because it is only a certain quantity of insecticide distributed properly on the plant, which kills the pests and not the volume of water required to give even distribution. In order to attain adequate coverage of the plants with a low volume of liquid, it is essential to break up the spray liquid into droplets which are considerably smaller than those formed in high volume spraying. The droplets, however, as we shall see later, should not be too small otherwise too many will be lost due to drifting, while on the other hand they should not be too large because then the coverage of the plants will be uneven.

Portable sprayers

Occasionally, use is still made of high pressure portable sprayers for treating field crops, particularly against localized infections or in places inaccessible to tractor-mounted sprayers. Low volume nozzles can be supplied also for these sprayer types. One to three nozzles are fitted to a bracket, thus enabling the plant rows to be sprayed from three sides at the same time. They give an output of approximately 60 to 120 litres of spray liquid per hectare.

Tractor-drawn sprayers

Incomparably higher outputs per unit surface are naturally obtained with sprayers which are mounted on the rear of the tractor. It was not until the development of the low volume sprayers that the tractor could be used for treating crops cultivated in rows, because this development meant that the tank dimensions and the weights could be reduced considerably and kept within tolerable limits.

Typical sprayers of this construction treat six rows simultaneously, and the tank, which often consists merely of a 50 gallon drum, is located behind the driver's seat. Below the tank is the pump which is coupled direct with the power take-off shaft.

Mostly the pumps installed are of the geared type, and they are very little larger than a man's fist. Recently, nylon roller rotary pumps, which are very resistent to wear-and-tear, have been introduced for this purpose, and use is also made of diaphragm pumps. Plunger pumps are seldom installed on these sprayer types because it is not necessary to produce higher pressures, and moreover the rotary pumps are smaller and cheaper. The emulsion is

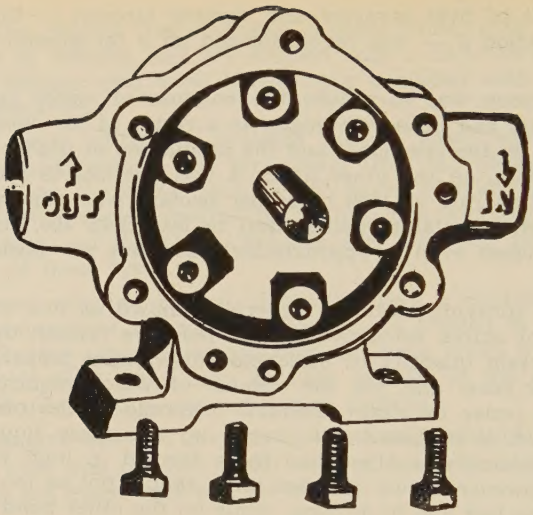

Fig. 1: Diagram of a nylon roller pump which is coupled direct to the power take-off shaft of the tractor

delivered from the pump to a pressure regulator, and a certain percentage of it is then passed on to the nozzle pipe while the rest backstreams to the bottom of the drum in order to keep the spray liquid constantly agitated.

The spray boom and nozzles may be termed as the most important part of the sprayer. It depends upon the adjustment of this assembly whether the plants will be adequately covered with spray droplets. For this reason, progressive growers should make a special point of selecting the right type of nozzle and adjusting it correctly.

For the treatment of particularly high field plants such as well-developed cotton, tobacco and maize, special sprayers with very high ground clearance have been constructed. These self-propelled ground sprayers have a clearance of about 5 feet or more, and can even be driven through high cotton stands without causing any damage provided the spacing between the rows is not too narrow. To protect the plants, all three wheels are covered by large crop saving fenders. In extensive cultures growing in flat country, which due to the height of the plants could normally be treated only by means of aircraft, these special sprayers which can treat up to 8 rows, soon prove to be worth their money especially in view of the excellent service they render.

In order to ensure a good coverage of plants, it is essential that:

1. The nozzle boom is set at a height corresponding to that of the plants.
2. The nozzles can be adjusted laterally to adapt them to rows located at various distances.

3. It must be possible to spray the rows of plants, dependent upon the stage of growth,

   a) only from above with one nozzle,

   b) from two sides at the same time with two nozzles,

   c) from above and from two sides simultaneously with three nozzles.

It is only when these three conditions are fulfilled that the grower will be able to obtain good control results with a low consumption of spray liquid.

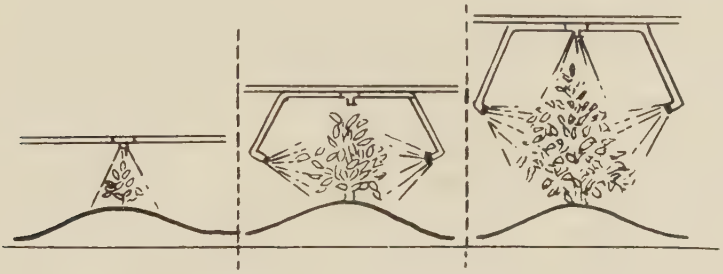

Fig. 2: Nozzle arrangement of a low volume ground apparatus in relation to the plant size

The following rough rule, based on cotton fields with a row width of 3 feet, may be applied for the water consumption of a low volume sprayer:

a) 1 nozzle and approximately 20 litres of spray liquid per hectare are used for treating plants up to a height of 25 cm.

b) For treating cotton plants 25 to 40 cm tall, two nozzles are used per row with a rate of application amounting to 25 to 50 litres of spray liquid per hectare. The nozzles should be set to spray the plants from left and right.

c) For treating cotton plants taller than 50 cm, three nozzles per row with an output of 50 to 80 litres per hectare should be used. For plants with dense foliage, more than 100 litres per hectare should be applied.

The nozzles should be set as far as possible, 15 to 25 cm away from the plants. If arms are fitted running downwards, which carry the nozzles spraying in a lateral direction, it will be necessary to insert a rubber buffer or some other form of shock absorber to protect the arms against impact. In order to obtain good control results at such low rates of application, the use of special nozzles is absolutely necessary. Nozzles manufactured by Messrs. Spraying Systems (Teejet) are installed in most sprayers. For applying insecticide emulsions, use should be made of types which give a spray pattern similar to a hollow cone. These nozzles produce droplets of relatively uniform size.

The following points should be given consideration by the farmer when selecting the type of nozzle he requires:

1. The insect to be controlled

When controlling leaf-chewing caterpillars (e. g. *Alabama)* or very mobile insects, the size of the droplet is not so important because the insect comes into contact with the lethal dosage due to its own movements.

On the other hand, an even distribution and a small droplet size are factors of utmost importance in the control of insects such as aphids which do not move about very much, because it is essential to hit as many pests as possible with the insecticide. The conditions differ somewhat for the application of a systemic insecticide such as "Systox" which even when applied in large drops, is absorbed by the plant, translocated in the leaf, and later kills aphids and spider mites. However, if this preparation is applied to give such a fine distribution that it immediately comes into contact with the pests, then it will produce a very rapid effect as a contact insecticide.

2. The plants

The larger and denser the leaf canopy of the plants, the more difficult it will be to wet the leaves growing close to the stem. It is a well-known fact that fine droplets penetrate much more easily into the plants than do large droplets. This may be attributed partly to turbulence (particularly with aircraft) and to the air current produced at the nozzles when spraying (with ground equipment). Another important factor which leads to good penetration, is the proper alignment of the nozzles to the plants. It is also essential that there is equal spacing between rows and that they are arranged in straight lines otherwise the plants will not be properly sprayed if they are not directly below the nozzles.

3. The insecticide

The fine apertures of low volume nozzles render it necessary to use insecticides only in emulsion form. Wettable powders soon lead to the filters becoming clogged up. The water used for diluting the insecticide must, without exception, be pumped or poured into the tank through a good filter. Moreover, the filter between the tank and the nozzle boom, and the filters fitted in the nozzles must be cleaned at regular intervals. The simplest way of doing this is to use an old toothbrush.

When the above-mentioned points are observed, the use of a low volume sprayer will give good control results, provided of course that the control is timed correctly. Admittedly, this type of sprayer needs more care and maintenance than a duster but in contrast to the latter, it can be used the whole day even in warm regions because the spray droplets (the majority are delivered from the nozzle to the plant in less than one second) are less exposed to air currents which means that there is less danger of drifting, added to which they adhere to the plants better than dust.

Controls carried out during the daytime by directing the spray into the open blossom of the cotton plants also make it easier to reduce the infestation rate of such pests as *Anthonomus* and *Heliothis* which prefer to remain in the flowers. It should be mentioned that the cotton flowers are closed in the early hours of the morning at a time when the dust-spreading aircraft are operating, which means that many pests concealed in the bloom are afforded good protection.

Fig. 3: Low volume sprayer with crop saving fenders, at the edge of a cotton field in Nicaragua

Fig. 4: "Gustavson" type low volume sprayer, with nozzles adjusted for spraying cotton. This apparatus sprays at the rate of 50 litres of insecticide emulsion per hectare. (Guatemala)

3. Application by Aircraft

In cases where limitations are set to the employment of ground equipment because of the presence of too many ditches dug for artificial irrigation, because of wet soil, or because the plants have grown too high for such equipment to be used, aerial dusting or spraying is the only other useful control method.

Moreover, the aircraft due to its high speed, can treat large areas in a relatively shorter time than a ground duster or sprayer, a factor which may be of great importance for the control of serious insect plagues.

As a result of these advantages of aircraft over ground equipment, there are today more than 7,000 airplanes in service in the U. S. A. solely for the purpose of pest control, 500 in Mexico and more than 100 in Central America. 90 % of the aircraft in service in Mexico and Central America are used exclusively for treating cotton plantations, and the position is more or less the same in the cotton-growing states of the U. S. A.

Aerial dusting

Following the last world war, large numbers of training planes belonging to the United States Air Force (mostly "Stearman" types) were sold to the general public at cheap prices. At the same time farmers and growers began to realise the importance of the new organic insecticides so that consequently a large number of the above-mentioned biplane type were bought and converted for the aerial application of insecticidal dusts, by fitting them with dust hoppers, agitators, feeding devices and venturi dust spreaders.

The construction of a duster aircraft is probably known in principle. The dust is always distributed through a venturi shaft located below the fuselage in the propeller air stream. The dust is fed in from above and swirled in the tapered section of the plane where the wind velocity is higher than the speed of the aircraft. The width of the dust swath can be varied within certain limits by adjusting the shape of the venturi.

In order to ensure that the dust will not be carried away by air current, and that the particles will settle quickly on the plants, the aircraft must be flown at heights of up to 3 feet above the plants. The downward movement of the dust is favoured chiefly by the downwind and the vortex produced by the bottom wing of the biplane. The vortex exerts an influence on the swath width, and also enables the dust to reach the bottom leaves of the plants, in certain cases also the lower surfaces of the leaves, when the plane is flying at the most favourable altitude. The degree of coverage is naturally very high when the dust is applied to dew-covered plants.

High-wing monoplanes like the "Piper Club", produce a weaker downwind and less turbulence within the plants so that the dust is not forced so well into the foliage as with a biplane or a low-wing monoplane. Consequently the dust settles more on the top leaves. For these reasons, a low-wing monoplane is the best type for applying dusts (and sprays, too). Recently low-wing planes designed for pest control work, with a high carrying capacity (types "Ag 1—3") have been introduced in the U. S. A.

The low velocity of descent of dust particles means that aerial dustings can only be carried out as long as there is no wind blowing, which would otherwise carry away part of the dust. A particular disadvantage are thermal upcurrents which always develop when the ground, under the influence of solar radiation, becomes hotter than the air layer immediately above it.

Fig. 5: Low volume sprayer in action, treating cotton plants approx. 3 feet tall. The conventional type 50 gallon drum can be seen at the rear of the tractor. Output: 50 litres per hectare. (Nicaragua)

Fig. 6: Low volume sprayer with boom for treating 8 rows, applying "Systox". The tank has a capacity of 1,000 litres. (Mexico)

In view of the fact that such thermal upcurrents carry the dust in an upward direction, aerial dusting has to be stopped as soon as these currents develop, as every experienced pilot will know. Due to this weather-susceptibility of dust, the working hours for aerial dusting are restricted to the early morning hours up to about 9 a. m., and to the time around sundown.

Aerial spraying

Airplanes equipped for the application of liquid insecticides, were still a rarity shortly after the war. The reason for this is that it is much more expensive to equip sprayer planes than duster planes, added to which good aircraft nozzles have been developed only in the last few years. Moreover, the problem of water supply often had to be solved by building water tanks close to the landing strips or by using large tank trucks. The sprayer plane, like the low volume ground sprayer, is less susceptible to weather influences such as wind and thermal upcurrents. Consequently, with the exception of a few hours around midday, it can be operated much longer during the day than a duster plane.

The introduction of the systemic insecticide "Systox", e. g. in Mexico, also contributed very much to the practice of aerial spraying being developed and employed on a much larger scale.

The construction of a sprayer apparatus for use in aircraft is in principle similar to that of a motorized field sprayer. It consists of a tank, pump with pressure regulator and shut-off valve, and the nozzle boom. In modern aircraft, it is possible to replace the sprayer installation by a duster in approximately one hour. By exchanging the base plate, the tank can be used as a dust container ("Piper Cub" and "Super Cub"). The tank is located at the thrust point of the fuselage. In the "Piper Cub" it is at the rear, and in the "Stearman" it is in front of the pilot's seat. The tank on the "Piper Cub" 135 has a capacity of approximately 300 litres, on the "Super Cub" up to 400 litres, and on the "Stearman" between 350 and 600 litres depending upon the horsepower of the engine.

The pump is mostly driven by a small airscrew fitted close to the fuselage. Sometimes it is located behind the engine to which it is coupled by means of a shaft, or else it is coupled to special hydraulic motors. The pump types mostly used are geared pumps or centrifugal pumps. The latter are extremely resistant to corrosion, but they do not always attain the pressures produced by geared pumps.

Just as on the field sprayers, the design of the nozzles and their arrangement on the spray boom is also of great importance in aircraft in order to obtain good control results.

Research work has recently been carried out in the U. S. A. on the spray droplet distribution pattern within the swath and its relation to the arrangement of the nozzles on the spray boom. It was established that the wing tip vortex has a strong influence on the spray pattern so that nowadays the nozzles are concentrated in certain form close to the wing tips, and are not arranged at equal distances as they are close to the fuselage.

The industry has brought out special nozzles for aerial spraying and one of the new types is illustrated in Fig. 9. The main difference between these and the nozzles used on ground sprayers is that they are equipped with a valve which automatically closes when the pump pressure drops below a certain

Fig. 7: Aerial spraying of "Systox" with "Stearman" type airplane. Rate of application: 50 litres per hectare. (Mexico)

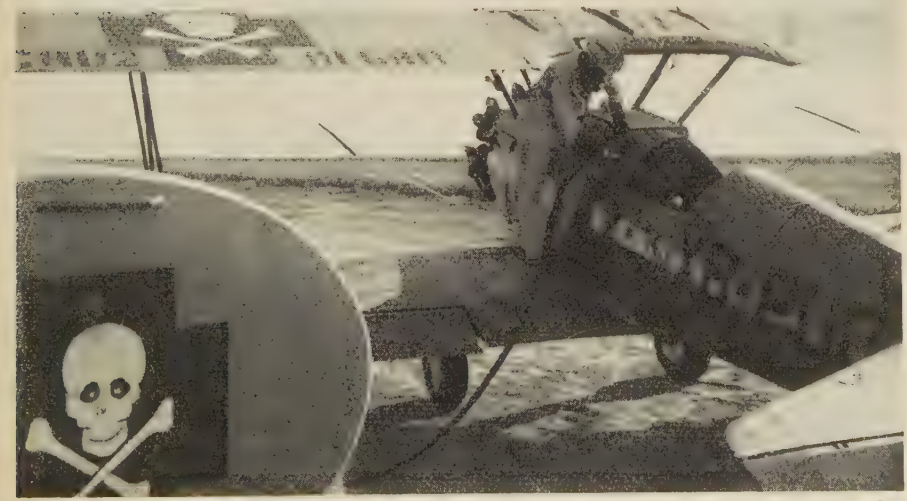

Fig. 8: Filling up the tank of a sprayer aircraft with "Systox", from a tank truck. The black cross is a firm trade-mark. (Mexico)

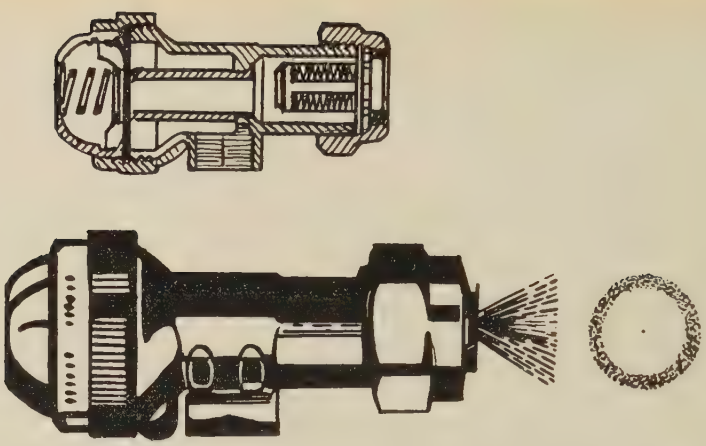

Fig. 9: Diafragma type airplane nozzles, top view and cross-section. The spray emulsion enters through the centre connection, presses the rubber membrane aside against the spring, and emerges from the nozzle after passing through a filter

adjustable level, e.g. 3 lbs. per square inch. This is reached through a diaphragm placed under spring pressure, which at higher pressures is forced aside by the liquid and exposes a pipe orifice leading into the open.

Nozzles of this construction not only close automatically, but do not drip, either.

Due to the high speed of the aircraft, they naturally have a high rate of flow and produce larger droplets than low volume ground sprayers, even though an aerial sprayer discharges at similar rates, e. g. 30 to 60 litres per hectare.

The droplets discharged from the nozzle orifice are broken up again by the slipstream of the aircraft, which in the case of the "Stearman" has a velocity of approximately 95 m.p.h. The degree at which the droplets are broken down increases proportional to the wind velocity. In order to obtain the smallest possible droplets, the nozzles are, therefore, not directed to the rear but are set pointing downwards or at an oblique angle to the front because then there will be a bigger difference between the velocity of the droplets and the air current, and consequently there will be a greater degree of fineness.

In addition to the above-mentioned nozzles, use was formerly made on a small scale of rotating disks or brushes, breaker bars or spray venturis for producing droplets. These devices, however, have not been able to compete with the nozzle boom fitted below (nowadays also behind) the wing.

In order to ensure that aerial spraying will be a success, it is essential that the working width of the airplane is not too large, and that it is marked by flagmen. While marking the swath, the flagmen should move forward against the wind each time so that they will be exposed as little as possible to the effects of the spray mist. To ensure that the downwind of the wing will be properly utilized for directing the droplets into the foliage, the swath of the sprayer plane should be exactly the same width as the wing span of the plane, or slightly wider.

Fig. 10: Filler orifice for pouring "Systox" into the tank of a sprayer plane; located on fuselage side. (Mexico)

Fig. 11: Filling up a sprayer plane with "Folidol". Old metal drums interconnected by pipes, are used as water storage tanks. The large drum on the right of the stand, holds 83 gallons equal to the tank capacity of the sprayer plane. (El Salvador)

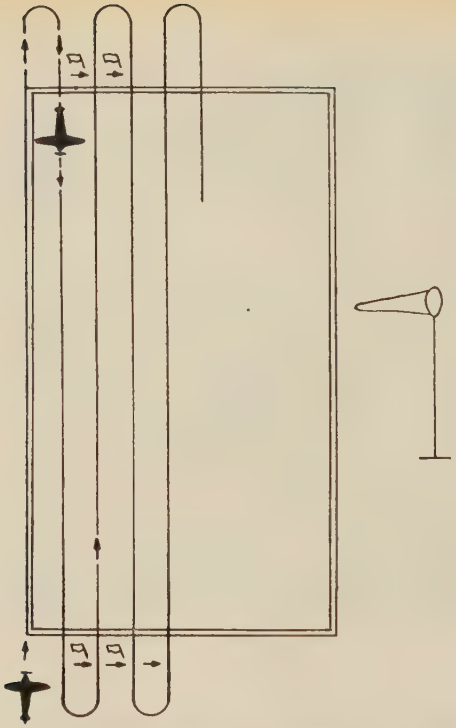

Fig. 12: Diagram of an airplane with flagmen who move forward against the wind during the treatment. It is advisable to place the flagmen outside the field because then they will hardly be troubled by spray mist, or in fact not at all

The planes can be ferried on the landing strip to a tank mounted on a stand at a height of approximately 6 to 12 feet in order to accelerate and simplify the filling-up procedure. The water can be run from the storage tank into the plane tank either through a swivelling knee pipe or through a thick hose. By employing this method, it takes approximately 30 to 60 seconds to fill up the plane tank. The concentrate or an emulsion previously prepared with water is either poured in simultaneously or mixed beforehand in the storage tank.

The water and the concentrate always flow through a filter which is placed in the tank opening while filling up.

In areas where the employment of sprayers planes is still a relatively new practice, the airplane tanks are mostly filled up from a tank truck, using a motor pump to discharge the water. By this method, it takes approximately $1^1/_2$ minutes to fill the sprayer tank. Very often, ditches or specially made water basins are used as water reservoirs (see Fig. 15).

4. Costs of Application

In view of the fact that the costs of application depend upon many factors such as wage levels, prices of equipment and fuel etc., which fluctuate considerably in the different countries, it is not intended to enter into this subject in detail. It should, however, be mentioned that insecticides, when compared on the basis of the active substance content, are more expensive in dust form than in the form of liquid concentrates.

Fig. 13: "Stearman" type airplane spraying cotton 5 feet tall. Flagman standing on the left in the front of the picture. (El Salvador)

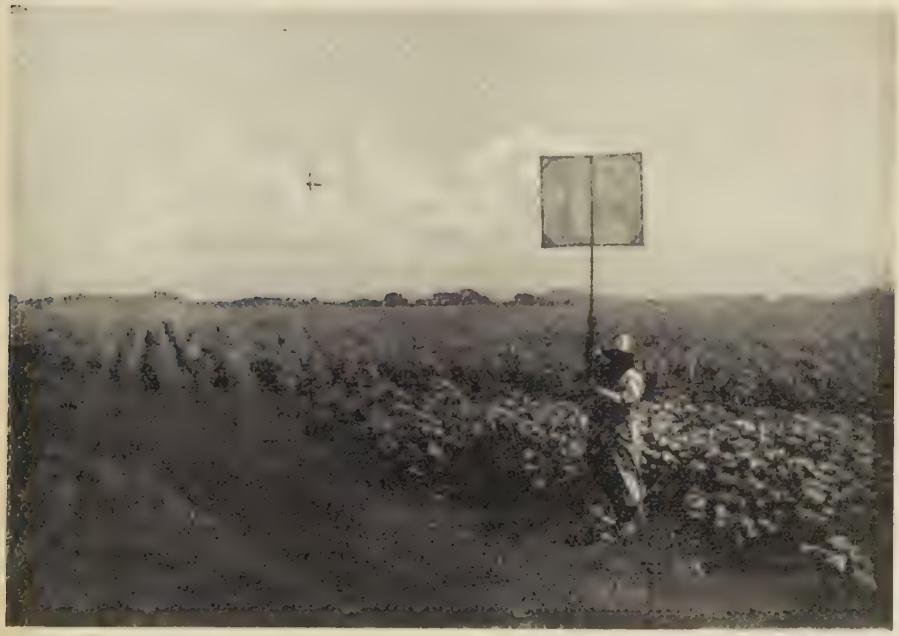

Fig. 14: Flagman wearing protective suit and rubber gloves, at the edge of a cotton field; plants 2½ feet tall. (El Salvador)

The costs of aerial application are cheaper for dust than for sprays. This will be obvious when it is considered that airplanes loaded with dust can treat a greater acreage because approximately 14 to 20 kg of dust are applied per acre and a sprayer plane applies approximately 40 to 50 litres (= kg) of emulsion per acre. But the continual increase in the number of sprayer planes being put into service at the expense of duster planes, is due chiefly to greater resistance of the sprayer plane to weather influences.

As insecticides in liquid formulation are cheaper than insecticidal dust preparations, there is no great difference in price between the total costs of aerial dusting and aerial spraying.

When a comparison of the ground equipment is made from this aspect, it will be found in most cases that the application of 300 grammes of active substance per acre in 50 litres of water, for example, by means of the low volume tractor-mounted sprayer is cheaper and more effective than with a ground duster or an airplane.

5. Particle sizes and weather influences

It is generally known that inert materials like talc or water used in sprayers are only applied mixed with insecticides through nozzles or similar installations in order to give as even a distribution as possible of small quantities of active substance on large surfaces.

The control result depends largely upon the degree of uniformity at which a certain quantity of active substance is deposited on the plants. Theoretically, this degree of uniformity is attained all the easier the greater a given quantity of liquid is broken down into very fine droplets or when dust with very small particle sizes is used.

As an example it may be mentioned that one droplet of 300 microns (1 micron equals 1/1000 mm) contains exactly as much liquid as 1,000 droplets each 30 microns in diameter. The breaking down of particles or droplets, however, cannot be carried too far because they then become more and more difficult to deposit on the leaves and are also very susceptible to weather influences. It is for this reason that nozzles are used in low volume ground equipment, which break down the main quantity of liquid into particles of between 40 and 100 microns. (100 microns correspond more or less to the thickness of a human hair.)

Aircraft nozzles have to produce droplets of considerably larger diameters because these droplets have a longer distance to travel from the nozzle to the plant, and therefore they are more exposed to drift and the danger of evaporation.

Table 1: Velocities of descent for water droplets in air.

Diameter of droplet expressed in microns	Velocity of descent expressed in cm/sec
5	0·075
20	1·20
50	7·50
100	27·00
150	48·00
200	65·00
500	200·00

Fig. 15: Filling up a "Piper Cub" type sprayer airplane, using a hand pump. (Guatemala)

Fig. 16: "Stearman" type airplane spraying "Systox" in Chihuahua (Mexico). The downward pointing Diafragma type nozzles are clearly visible on the lower wing surface.

The velocity at which droplets of different sizes fall, can be calculated quite easily or be determined experimentally. For example, a water drop 200 microns in diameter has a velocity of descent amounting to 65 cm per second, while the velocity of descent for a droplet 100 microns in diameter is 27 cm per second. A droplet with a diameter of 50 microns, however, falls at a velocity of only 7·5 cm per second.

Droplets of the above-mentioned sizes are produced by airplane nozzles. From the example given, it is clear that large droplets very soon reach the plants whereas small droplets may easily be carried away by air currents, in particular by thermal upcurrents when the upward movement of these currents is greater than the fall velocity of the small droplets (see Table 1).

It must also be considered that water in small droplets may evaporate while in travel due to warm, and in particular dry air so that in the end only a small particle of insecticide is left suspended in the air. The calculation of the life of droplets of different diameters in relation to relative humidity, temperature and other factors would be going too far beyond the scope of this paper. However, as an example it may be mentioned that the life of a water droplet 100 microns in diameter amounts to $\sim$ 17 seconds in an atmosphere of 30 ° C and 70 % relative humidity (see Table 2).

A close study of Table 2 will show that the rate of evaporation for small droplets of water depends chiefly upon the saturation deficit of the air, i. e. the life of small droplets in a dry atmosphere is very short.

Consequently a sprayer aircraft, for example, can operate to greater advantage and with smaller droplet sizes in the wet tropics where there is a relative humidity of 90 % and above than in arid regions of cultivation where there is a possibility of the fine fraction of spray droplets evaporating before it reaches the plants.

Table 2: Life periods of water droplets in relation to temperature and relative humidity.

Diameter of droplet expressed in microns	Temperature ° C	Rel. Humidity %	Life period expressed in seconds
100	20	70	20
100	20	40	9
100	30	70	17—18
100	30	40	8
100	40	70	16·8
100	40	40	7·8
50	20	70	5
50	20	40	2
50	30	40	1·9

Insecticidal dusts made up of particles with a diameter of less than 40 microns, fall at velocities amounting to only a few centimetres per second. This explains why the small dust particles, in particular, depend so much upon the weather influences, and why on the other hand they are better able due to their small size to penetrate through the vortex produced by the airplane into dense foliage than the larger spray droplets. These are chiefly deposited on the upper surface of the top leaves.

The concentrated deposit of spray droplets on the upper plant parts is, generally speaking, not a disadvantage because on the most important crops which require constant treatment with insecticides (cotton), the buds, flowers and young fruit to be protected, as well as the chief pests are all on the shoot tips, and are, therefore, given full coverage by the insecticide. It is only in special cases where pests prefer to lay their eggs lower down in the foliage (*Estigmene* and *Pectinophora*), that a dust treatment may be of greater advantage than a spray application.

Precautions

The precautions which have to be laid down for the handling of insecticides depend not only upon the toxicity of the preparations to humans and warm-blooded animals but also to a very large degree upon the application technique, in other words upon the type of equipment used (aircraft, tractor applicators, portable dusters), furthermore upon the formulation of the preparations (spray, dust, aerosol).

The finer an insecticide is broken down when applied, e. g. as dust or as aerosol (its particles have a minimum velocity of descent), the easier it will be for the fine insecticide particles to penetrate into the respiratory organs of humans, insofar as this is not rendered impossible by the use of respirators.

It is, therefore, a firm rule always to wear a dust mask (with filter for suspended material) when applying dust with hand equipment and there is a risk of inhaling the dust.

The same applies to flagmen who signal the course for sprayer aircraft, particularly in warm and dry climates because in these conditions the water content of small spray droplets may evaporate so that the active substance remainder is often left suspended in the air for long periods and does not reach the plants.

For the very same reasons, the nozzle boom of low volume tractor sprayers should always be installed at the rear of the tractor so that the driver cannot come into contact with the spray droplets in normal wind conditions.

Loading gangs who have to handle liquid spray concentrates should always wear rubber gloves to protect their hands. As a rule, the necessary precautions are indicated by the manufacturers of the insecticides on the labels of the packings. Provided these precautions are strictly observed, there will be no danger whatsoever to the operator.

Summary

A comparison of the application technique practised in North Europe with the methods employed in tropical countries, brings the following points to light:

Under the decisive influence of the American equipment industry, the low volume ground equipment and the airplane have been introduced on a broad basis during recent years for the treatment of field crops in the U. S. A. and in many countries of Central and South America.

Ground sprayers and sprayer aircraft are gradually replacing dusters in those countries where dust applications are still predominant (Mexico, Nicaragua).

This trend may be attributed firstly to the fact that spray droplets are less affected by thermal upcurrents and wind, and secondly to the fact that

liquid insecticide formulations based on active substance are offered to the farmer at cheaper prices than dusts. Consequently, liquid insecticide formulations are being given preference over dusts on an every increasing scale.

In conditions where ground equipment can be used, the motorized low volume sprayer equipped for row treatments will generally prove to be the most economical machine although with respect to output per unit of area the airplane is considerably superior to it.

In tropical conditions, aircraft dusting which gives a more even plant coverage than is possible by means of aircraft spraying, can only be carried out successfully during the morning hours.

It is explained by means of tables that the life of water droplets is influenced chiefly by relative humidity and secondly temperature. Due to their higher velocity of descent, spray droplets are far less affected by convection than the many finer dust particles. Consequently, sprayers can be operated as a rule all day long.

Results of the Control of *Phytophthora infestans* de By. between 1950 and 1955

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Records show that the first serious losses caused by late blight in Europe were in 1845. At that time the cultivation of potatoes was in danger of being brought to a complete halt because the damage inflicted continued to remain almost as serious as in the first year until 1850. According to the records, there were apparently only local occurrences of the dreaded disease in the following years until in 1916 it broke out on a devastating scale. The damage caused during that year was estimated at more than one thousand million gold marks. Even today the losses brought about by late blight infections are very high, and many growers capitulate to this disease because they have not yet realised the value of a systematic control.

Late blight of potatoes is caused by *Phytophthora infestans* de By., a fungus which has been proved to originate from America. Scientists began to concentrate their attention on the biology and control of this pathogen immediately following the first serious outbreak of the disease. Very soon differences were established in the susceptibility of several potato varieties to the disease. Unfortunately difficulties were encountered in the breeding of resistant varieties because *Phytophthora infestans* developed physiological strains varying in their power of aggressiveness. Eight biotypes have already been isolated to date from wild and cultivated potatoes, and the development of more is expected regularly (Braun and Riehm, 1950). This means that chemical controls are indispensable even today. Regular losses due to late blight are anticipated particularly in North-West Germany.

Extensive tests were conducted from 1950 to 1955 in Westphalia with the object of obtaining exact data showing whether it is economical to carry out a systematic control of late blight. Table 1 reveals that the average increases

Table 1: Possible yield increase following systematic control of late blight. Results of 754 tests (1950—1955).

Test year	No. of tests	Average yield increase expressed in 100 kg per hectare	Yield increase expressed in %
1950	221	49·6	20·4
1951	350	53·7	23·5
1952	98	60·4	19·2
1953	49	92·0	25·5
1954	18	45·7	16·4
1955	18	45·4	21·1
	754	55·6	20·9

in yield during the years the tests were conducted, amounted to approximately 21 % as compared with the untreated fields.

Table 2 gives the total potato yields harvested in Westphalia from 1950 to 1955. The calculation of a yield increase as a result of systematic late blight controls, was based on the assumption that the yield increases established in the tests apply to only about 50 % of the total harvest because a percentage of the potatoes is less susceptible, and controls are carried out on susceptible varieties by cautious growers. When the price of potatoes on November 1st of each year is taken as a basis, and the spraying costs for three treatments of half the acreage used for growing potatoes are deducted from the surplus, a net surplus averaging 23,756,000 DM is obtained for each of the six years. A reduction in value due to the production of fodder potatoes was not allowed for in this calculation. The increase in the net surplus, however, is again proved to be a fair calculation by the fact that spraying with fungicides not only

Table 2: List of potato yields and possible yield increases as the result of late blight controls in Westphalia for the period 1950 to 1955.

Year	Total harvest expressed in 1000 tons	Yield increase * expressed in 1000 tons for 50 % of the harvest	Price of potatoes per ton	Surplus expressed in 1000 DM	Spraying costs ** expressed in 1000 DM	Net surplus expressed in 1000 DM
1950	2660	271	89·00	24,119	3737	20,382
1951	2406	282	112·00	31,584	3864	27,720
1952	2714	260	127·00	33,020	5065	27,954
1953	2348	299	106·00	31,694	4690	27,004
1954	2631	215	95·00	20,425	4545	15,880
1955	2241	236	120·00	28,320	4724	23,596
∅	2500	261	108·00	28,193	4438	23,756

* cf. Table 1

** The calculation of the sprayings costs was based on three treatments of 50 % of the total acreage set with potatoes. In addition to the costs of the preparation, 24 DM per hectare were calculated as wages for the spraying team in respect of the three treatments.

brought about a bigger yield but also raised the content of starch, an increase which was not included in the computed figures. Moreover the decrease in the numbers of tubers infested by brown rot, observed in the sprayed plots in practically every test, was not credited to the net surplus, either. Approximately 10 % of the total potato yield of the Federal Republic is harvested in Westphalia. Consequently the average yearly losses for the whole of the Federal Republic are estimated at 237,560,000 DM because similar results were obtained also in investigations conducted in other areas (Rieth, 1956). These figures clearly show that the control of late blight must be introduced in practical farming on a far greater scale than ever before if the returns in agriculture are to be increased.

Late blight control test, 1955, with "Cupravit" (Ob 21), at a farm in Emmeln. "Bona" variety.
Left: not sprayed. Right: sprayed three times.
Yields: untreated fields — 27,500 kg per hectare; sprayed fields — 33,000 kg per hectare.

When it is considered that such high losses are suffered by farmers every year due to late blight infections, and that control measures are only carried out on a very small percentage of the total acreage set aside for potato growing, the question automatically arises what reasons the farmers and growers have for adopting such a sceptical attitude towards the control of late blight despite the proved good effect of the control preparations:

1. Many farmers are unfamiliar with the development of the pathogen of late blight. Consequently sprays are not applied at the right time.

2. There is a very slight chance of sprays proving successful when they are applied at the wrong time, or when insufficient preparation and inadequate quantities of water are used.

3. It is often feared that injuries caused to the plants when sprays have to be applied to well-developed stands, will destroy the advantage of a treatment.

4. Some farmers are of the opinion that only a few varieties (e. g. "Bona") are attacked by late blight.

In my opinion, there is no necessity to give a detailed description in this paper of the biology of *Phytophthora infestans*. But if more and more farmers are to be encountered in future to carry out systematic controls of late blight, it will be necessary for plant protection technicians acting in an advisory capacity to make the farmers familiar with the biology of the pathogen of late blight, to inform them of the nature of the injuries inflicted by this disease, and to explain what counter-measures should be taken. Even today, there are two great errors which are repeatedly made in the control of late blight:

1. The first spray is often applied when the potatoes are about 10 cm tall. Even though two more sprays are carried out at intervals of 10 to 14 days as recommended, the success of the treatment will only be very slight when there is a late occurrence of the disease. Mostly the reason given for early spraying is that on the one hand the first leaves must also be given a coating of spray, and that on the other hand damage will be caused to well-developed plants when the sprayer is driven through the rows.

2. Then there is another group of farmers who every year had hoped that late blight would not occur. They do not start controls until the injuries are clearly visible in the stand. They forget that the leaves must have a protective coating of spray before the spores of the fungus reach the plants. The best time for spraying will have been missed if the spores have penetrated with their germ tubes into the plant tissue and spots are already visible. The disappointment felt by the farmers because there is hardly any prevention of damage despite the application of sprays — often only one spray is applied — frequently leads to them completely refusing to have anything to do with late blight controls in future.

In order to preclude these errors, it must be continually pointed out to farmers and also to contractors who carry out pest control work, that the fungus requires a relatively high temperature and a fairly high relative humidity in the stock, in order to develop and propagate. These two conditions, however, do not prevail as a rule until the rows begin to close up. But as soon as the stock is more or less compact, and liquid water forms on the leaves at temperatures high enough for the spores to germinate, the fungus penetrates with its germ tubes into the small leaves of the plants. Consequently, the aim of all control measures must be to prevent this germination or to reduce it to a minimum.

The official plant protection service has set up an organisation to assist the farmer in choosing the best time to apply the sprays. This organisation arranges for warnings to be broadcast over the radio and published in the newspapers, but they are merely of a general nature in respect of *Phytophthora infestans* because it is practically impossible to allow for local differences in the development of the plant host and the parasite when formulating the announcements

giving warning to the farmers. It also depends upon the development of the plants and upon the frequency and amount of rainfall in deciding what further measures need be taken after the first spray (Goossen and Eue, 1955). The development of the plants is the determinig factor particularly for carrying out the second spray because the first spray is followed by that period when the growth of foliage is most vigorous. According to studies made by Goossen and Eue (1956), in fourteen days there is approximately a threefold increase in the surface area of the leaf during this period of vigorous growth. This means that two-thirds of the leaf surface have no coverage of spray wash.

Another important factor in the control of late blight is the rate of application for preparation and water. Tests carried out by the Plant Protection Division of the Chamber of Agriculture in Westphalia-Lippe, to establish the most suitable rates of application, showed that in normal weather conditions 4 to 5 kg of preparation per hectare must be applied for 45—50 % copper

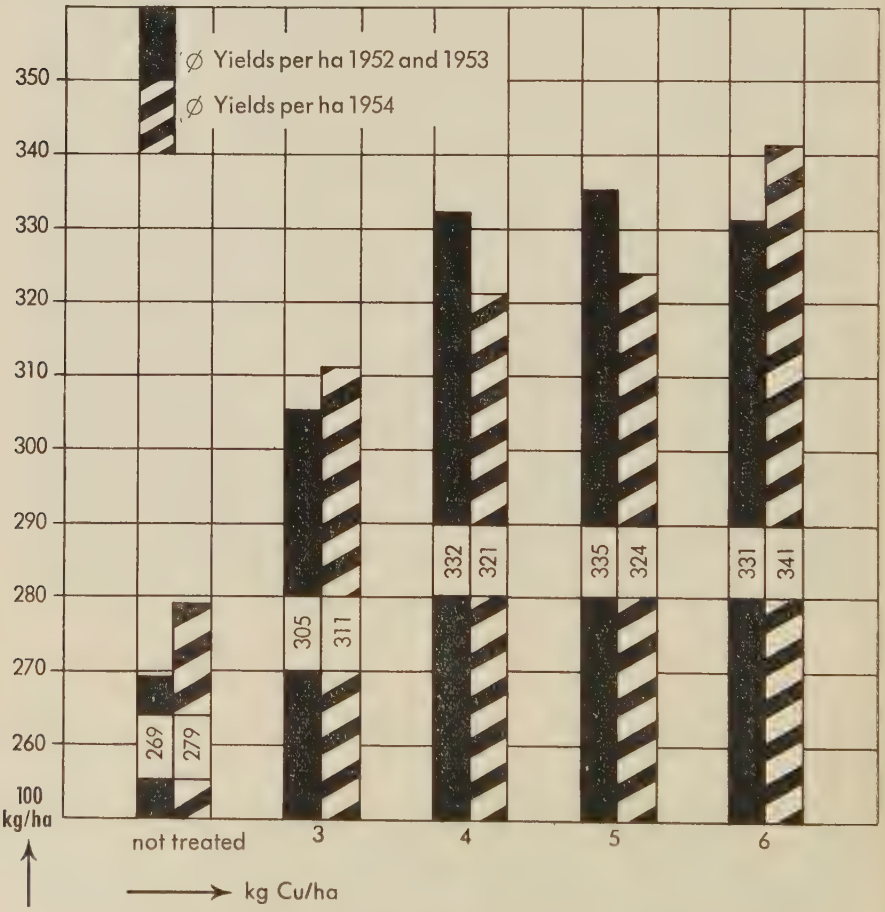

Fig. 1: Yield increase for potatoes, obtained with varying rates of application (1952—1954)

oxychloride and 35 % cuprous oxide (Dame, 1953). Lower rates will not produce satisfactory results. On the other hand, if more than 5 kg per hectare of a standard copper preparation are sprayed, it is doubtful whether the yields will be increased, at least in years when weather conditions are normal (see Fig. 1).

It is only when there is a very large amount of rainfall, as in 1954 for example, that it is worthwhile increasing the rate of application for copper by approximately 1 kg per hectare. Ratings of stands, carried out over several years, showed that when the concentration was increased excessively, slight injuries were inflicted on the foliage although they did not cause any considerable decreases in the yield.

The organic preparations included in the tests during the last two years, did not affect the foliage of the potato plants even when applied in large overdosages. It was established from these tests that Zineb must be applied at a rate of at least 1·5 kg per hectare in favourable weather (1955) or better still at a rate of 1·8 kg per hectare when the weather conditions are not so good (1954), in order to obtain yield increases equal to those produced with copper oxychloride. It is highly probable that the weaker adhesive property of Zineb reduces its degree of effectiveness. Perhaps better control results would be obtained by shortening the interval between sprays, although the concentration would have to be weakened (1·2 kg/hectare) in view of the greater frequency of the treatments, to ensure that the controls continue to be a profitable practice. "Captan" did not produce satisfactory results even at rates of up to 2·4 kg per hectare, and therefore for reasons of economy it cannot be considered for use in the control of late blight (see Table 5).

In all the tests, it was definitely established, as did Blunck (1949), Schumacher (1951 and 1953), Goossen (1952 and 1953) and Dame (1953), that at least 400 litres of water per hectare must be used for spraying. The highest yield increases are produced by treatments in which 600 litres of spray wash per hectare are applied. A greater output of water leads to a drop in the effect of the spray. Investigations by Goossen and Eue (1955) have revealed, however, that with the preparations and equipment available today, it is not possible to give the leaves a full coverage of spray wash and thus obtain a 100 % control success.

The opinion is often expressed by farmers, as already mentioned, that treatments with tractor-drawn equipment can only be carried out up to the time when the rows begin to close up, without causing injuries to the stand. Later treatments would result in considerable damage being caused to the plants by driving the sprayers through the rows, so that yield increases could hardly be expected. However, if sprayers fitted with a power take-off shaft, and equipped with a boom 10 metres long, are used for controlling late blight, 16 rows would be treated assuming that the plant has a width of 62·5 cm. But only two rows of plants, in other words 12·5 %, would be damaged by the wheels of the sprayer. Provided the track of the vehicle is correctly adjusted so that the hills will not be damaged, there will not be a decrease in yield. This was confirmed in tests carried out by the Plant Protection Division of the Chamber of Agriculture (Table 3) to investigate this point. In these tests, the applications were made with horse-drawn sprayers (boom of 5 metres), fitted with iron-rimmed wheels. The treatment, with three to four replications, was carried out so that the horse and sprayer were always driven along the same rows. The yield decrease calculated in the following table for 14 tests, is within the limit

Table 3: Tests in which the rows were evaluated separately according to whether spray equipment was driven through them or not (14 tests).

	Yield expressed in 100 kg per hectare	Yield increase	
		100 kg/ha	%
Untreated	278·60	—	—
Treated A	338·60	60·00	21·4
Treated B	333·40	54·80	19·7
Yield decrease in B as compared with A	5·20	5·20	1·8

A = Sprayed 3 to 4 times, rows not touched by equipment
B = Sprayed 3 to 4 times, horse and sprayer driven through rows for each treatment

of error, thus refuting the assertion of many farmers and growers that serious damage would be caused when spray equipment is driven along the rows in well-developed stands.

When stands are rated, it is observed that the different varieties of potatoes vary in their degree of susceptibility to *Phytophthora infestans*, a fact also stated in the Handbook of Plant Diseases. According to Braun-Riehm, early varieties are attacked more severely than late varieties. This, however, is probably a case of apparent resistance because the late potatoes do not reach a susceptible stage in their development until it is already so late in the year that the prevailing conditions are no longer favourable for the mass reproduction of the fungus. Differences in apparent resistance, according to Braun-Riehm (1950), may be due to the fact that certain varieties may have a more or less vigorous top growth stimulated by local factors and fertilization. A variety completely resistant to *Phytophthora*, has never been found. Tests carried out by the Plant Protection Division, Münster, show that in years when no late blight controls are carried out, considerable decreases in yield may be caused even among late varieties known generally as being only slightly susceptible. Late potatoes are damaged very seriously when conditions most favourable for the development of *Phytophthora infestans*, prevail in late Summer. A study of the varieties of the different groups used in the 1950—1955 tests, provide us with the following picture:

Late blight controls need not be carried out on early varieties provided development is normal and they are lifted in good time. However, if early varieties happen to be injured due to late frost so that they cannot be harvested

Table 4: Yield increase as a percentage, for varieties of the different groups (tests 1950—1955).

Group	1950	1951	1952	1953	1954	1955
Earlies	22·5	23·6	14·1	—	—	15·3
Middle-earlies	20·7	25·6	19·1	31·4	12·3	25·6
Middle-late	22·3	20·4	20·5	19·9	26·6	23·4
Late	14·3	23·5	21·5	20·3	24·1	14·8

until later than usual, it will be advisable to carry out a late blight control (e. g. 1950—1951) which, as a rule, can be limited to one or two sprays. The middle-early potato varieties include the very susceptible "Bona" variety which was used in the majority of the tests. In practically all years, with the exception of 1954, most of the losses were caused in the "Bona" rows due to the occurrence of late blight, and it was also with this variety that the highest yield increases were obtained in comparison with untreated plots, following application of sprays in the specified manner. The application of fungicides will also lead to considerable increases of yield in fields of middle-late and late varieties. These yield increases fully compensate for the costs of preparation and labour, and in fact this expenditure was quite justified during the period 1950—1955 when the yield increases were not so great. Frequently, late blight controls are carried out much too early on the middle-late and late varieties so that the yield increases are small. In view of the fact that these varieties do not reach the susceptible stage until later, they should be given their first spray at the same time as the middle-early potatoes receive their second treatment. The treatment should then be repeated once or twice depending upon the prevailing weather conditions.

In order to check the efficacy of several groups of preparations, the Plant Protection Division of the Chamber of Agriculture, Westphalia-Lippe, carried out 36 tests in cooperation with the agricultural colleges. From the results listed in Table 5, it will be seen that green copper is slightly superior to red copper and Zineb. However, as only the results of two-year tests are available, further investigations will have to be carried out. It is probable that there will not be a superiority of green copper under different climatic conditions.

Table 5: Yield increase following late blight control (varying effect of different groups of preparations).

Group of preparation	Yield expressed in 100 kg/ha	Yield increase		Starch %	Relative yield of starch per unit of area
		100 kg/ha	%		
Untreated	247·01	—	—	11·18	100
Copper oxychloride (45 to 50 % Cu) 5 kg	292·58	45·57	18·4	12·51	133
Cuprous oxide (35 % Cu) 5 kg	284·23	37·22	15·1	12·21	126
Zineb 1·5 kg	285·56	38·55	15·2	12·29	128
"Captan" 1·5 kg	273·86	26·85	10·9	12·00	120

Summary

It is essential that farmers and growers are informed about the biology of *Phytophthora infestans* so that the sprays will be applied in good time, in order to keep the annual losses caused by late blight down to a minimum.

The recommended rates of application are 4 to 5 kg per hectare for copper preparations and 1·5 to 1·8 kg per hectare for Zineb. The preparations should be applied mixed with at least 400 litres, or better still with 600 litres of water per hectare.

No losses will be caused by driving spayers through the rows provided the work is done efficiently.

The control of late blight is absolutely essential not only on middle-early varieties but also on middle-late and late potatoes.

In two years of tests, copper oxychloride proved to be the most effective preparation under the climatic conditions of Westphalia.

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Contribution to the Technology and Technique of Atomizing in Pest Control

by Kurt Schütz

The technology of atomizing includes a number of rules, several of which still appear in the form of questions, e. g. the most suitable droplet size in relation to the rate of liquid applied per hectare, the travelling velocity of the droplets, influence of the quantity of air applied and the velocity on drift, penetration by and deposit of droplets etc. The technique of atomizing deals with the apparatus and its technical elements required to apply the technological

rules in practice. In plant protection, technology and technique are very greatly dependent upon each other. They must, therefore, be dealt with in close relation to one another particularly in the development stage. The multiplicity of the problems appertaining to agricultural chemistry, biology, technique and practical farming, therefore, involves many special studies. An attempt has been made to adapt this technological-technical contribution as far as possible to the overall problem. For this purpose, it is necessary to give just as close attention to the past as to the future. It should also be pointed out that in this paper, spraying is understood to mean distribution of liquid without addition of blast air, and atomizing to mean distribution of liquid with addition of blast air.

I. Technology of Atomizing

The development of the atomizing method for application in agriculture began in 1940 with the foam mist applicator. According to present-day conceptions, this is to be interpreted as an atomizing apparatus. The error in the definition is understandable because a distinction between the terms "mist application" and "atomizing" was not made until later. The chief feature of that process which was new at the time, was that it brought about a reduction of the conventional quantity of spray wash from 1000 litres per hectare to 200 litres per hectare. The plan was welcomed by a large majority — reservation being made for biological efficacy — while others laughed at the idea predicting biological inefficacy. Such remarks strengthen the designer's tendency to apply caution when departing from practices based on old experience. For this reason an inquiry was organized and studies were conducted to establish the reasons which had led to the introduction of the 1000 litre per hectare rate of application, and why this rate had been retained for so many years. From the three branches of pest control, namely biology, chemistry and technique, an exact answer was obtained only from the technical side. Summarized, this answer was to the effect that the traditional rate of 1000 litres per hectare is based on apparatus technicalities because in the main the quantity discharged is determined by the size of the nozzle bore, and at that time the methods employed for grinding chemical preparations did not give a product fine enough to eliminate the danger of the nozzles becoming clogged up so that they could not be made with a bore of less than 1 to 1·2 mm. The other factors, such as the distance between nozzles on the boom, liquid pressure and speed of the apparatus, could only be varied within narrow limits. This automatically led to a rate of application amounting to approximately 1000 litres per hectare.

It was only logical that following this purely technical discovery, a technical aim should be set for the design of the first field atomizer (foam mist applicator), namely to reduce the rate of liquid application by one fifth (200 litres per hectare) combined with larger nozzle bores *. It was merely as a point of secondary importance that allowance was given to the fact that the smaller droplets produced should be transported in the air current because they cannot absorb a larger amount of kinetic energy $\frac{m \cdot v^2}{2}$ which would suffice for them to be projected far enough. From the production point of view, these atomizers were a success. (Approximately 8000 have been manufactured and sold in Leipzig since the war.) The success achieved encouraged other designers to produce similar effects in a more simple technical manner by using so-called

* Kurt Schütz: „Spritzung mit Schaumnebel". „Die Technik in der Landwirtschaft", 1943, No. 3.

economizers. On principle, the water-economizing units have become established in agricultural work. Experts, however, are by no means unanimous even today on the actual extent of the economy in water used. Even the modern chemical preparations, of which for example hormone products present a danger to neighbouring fields and highly toxic preparations to humans due to drifting, have an influence on the different opinions formed. To prevent drifting caused by natural wind, there is a demand for larger droplets, i. e. higher rates of liquid application. In other cases *(Phytophthora)*, complaints are raised about poor depth penetration, or in the case of caustic weed killers (DNC) about reduced dripping power when low rates of application and small droplets are used. On the whole, there is an obvious tendency to increase the rate of application again to 400—800 litres per hectare, at least for a large number of control practices. From the economic aspect, this development would be regrettable for agriculture. The reasons, of course, must be acknowledged as being sound, that is from the aspect of the present stand of technique which is predominantly s p r a y i n g technique.

The stand of technique is a reflection of the respective technological discoveries. Their perfection also brings about a change in technique, a change which in fact is often fundamental. Applied to the subject under discussion, the question as to the reasons for the traditional rate of application of 1000 litres per hectare was raised again in 1947 with the result that the explanation given at the time purely in respect of apparatus technicalities was found to be incomplete. The supplementary answer is as follows:

In agricultural pest control, the droplets have to penetrate s p a c e s filled with a maze of leaves, stems and branches. The task to be fulfilled is to produce from a minimum quantity of liquid, a maximum number of droplets of the most favourable size, and to cause a high percentage of these droplets to be deposited on the plant parts, attaching great importance to the uniformity of distribution. Both the evenness of distribution and the deposit of the droplets require complete wetting of the plant stand whereby the droplets should still continue to travel at a sufficiently high velocity even in the farthest away zones of the space to be wetted. The maze of plant parts offers considerable resistance to thorough wetting. The degree of resistance increases proportional to the density and the volume of the stand. The greater the resistance, the larger must be the application of wetting energy which is effective only as kinetic energy $\frac{m}{2} \cdot v^2$ (m = mass $\frac{G}{g} = \frac{kg}{9{\cdot}81}$; v = velocity $\frac{m}{sec.}$).

Practical limits are set to the velocity by the apparatus (pressure) and due to the susceptibility of the plant parts to injury. Therefore, if the velocity "v" is restricted, then the kinetic energy required to wet the stand can only be produced by an adequate proportioning of mass "m". This leads to the following conclusion:

The degree of wetting when treating a plant stand depends directly upon the size of the mass set in motion.

Consequently, each plant stand to be wetted requires a mass set in motion having a minimum corresponding to its resistance. Our predecessors working on biology and plant protection technique found that when spraying fields — chiefly against *Phytophthora* in fully developed potato stands — 1000 kg of liquid per hectare are required to give adequate wetting. Tests carried out in our time confirm that the degree of wetting is much lower when only 600 litres per hectare are applied by the spraying method. Thus the traditional rate of 1000 kg per hectare — in addition to the explanation purely in respect of

apparatus technicalities — is completely justified, and compels us to draw our conclusions.

Pest control, due to the increasing scale on which it is being carried out, necessitates more and more work being done in the field. Consequently there is a demand for labour-saving methods, which is more urgent than ever before. It is, however, quite definite that production progress can only be attained by reducing the quantities of liquid to be applied per hectare. This antithesis to the thesis of the necessary 1000 kg wetting mass per hectare can, theoretically, be bridged over quite easily by the atomizing method insofar as spraying is understood to mean an application method in which air is used.

Air is also mass ($1\,m^3 = 1{\cdot}293$ kg). It can, therefore, also be used as a wetting mass, just as we know it in connection with the atomizer blower used for treating trees. The necessary wetting mass can be composed of liquid in drop form and air, also in agriculture. Assuming it to be correct that 1000 kg per hectare should be applied in agriculture — and today I am convinced that this is correct — there is a possible solution to the problem by making up this quantity of 1000 kg with 200 kg of liquid, for example, and 800 kg or $\frac{800}{1{\cdot}293} = 620\,m^3$ of air. Assuming the actual atomizing time to be fifteen minutes per hectare, the following quantity would have to be applied per minute using a corresponding apparatus: $\frac{200}{15} = 13{\cdot}3$ litres in drop form mixed with $\frac{620}{15} = 42\,m^3$ of air. The proportion by volume of air to liquid is $\frac{42000\,l}{13{\cdot}3\,l} = \frac{3160}{1}$.

Fig. 1

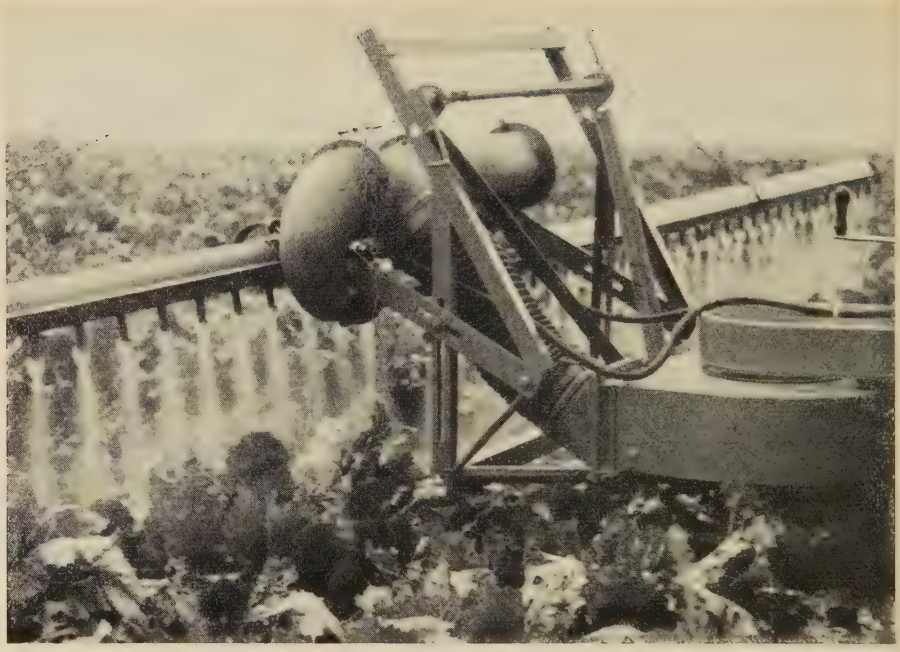
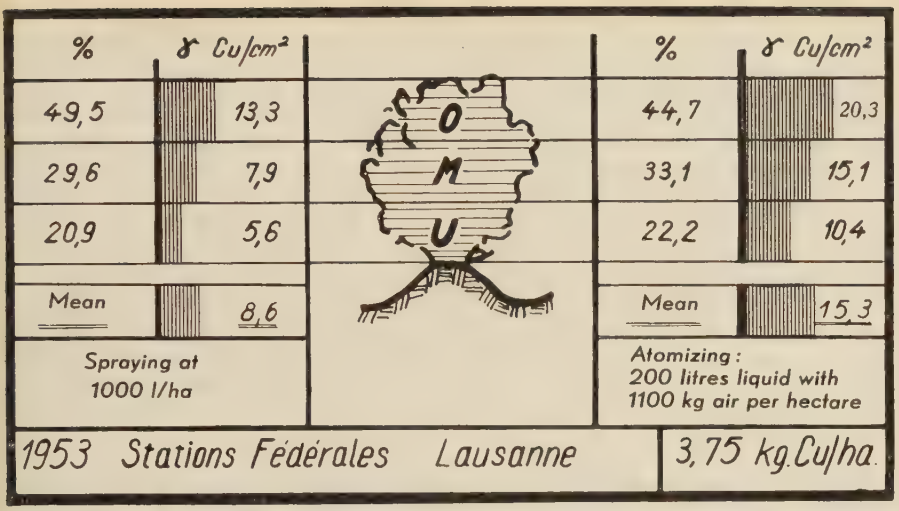


Fig. 2

The "Aero" Boom was developed on the basis of these deliberations (Figs. 1, 2). It has an output, expressed as the total mass, of at least 1200 kg per hectare, made up of 100 litres of liquid and 1100 kg of air. The quantity of liquid can be adjusted between 100 and 600 kg per hectare. The quantity of air remains the same at approximately 1100 kg per hectare so that the total output increases to 1700 kg per hectare. The replenishment of the reduced quantity of liquid by air to give a total quantity of at least 1200 kg per hectare is the new feature in the technology of the field atomizing method. The technique of what has actually been realized will be discussed later.

From what has been said, the impression is gained that the development of the field atomizer has been held up by insufficient knowledge of its technology. It is understandable that the intensity of wetting must suffer when, with the spraying method, the wetting mass of 1000 kg is reduced, for example, to 400 kg without any compensation, or when using the known field atomizers, such a small quantity of air is applied that it holds no weight as compensation *. The obvious question would now be to ask whether the above-mentioned tendency to use again larger quantities of liquid per hectare, is not to be

* Similar ideas are expressed by Goossen.
Dr. H. Goosen, Pflanzenschutzamt Münster: „Möglichkeiten und Grenzen einer Herabsetzung der Wasseraufwandmengen bei Pflanzenschutzmaßnahmen im Feldbau." „Gesunde Pflanze" 1954, No. 11.



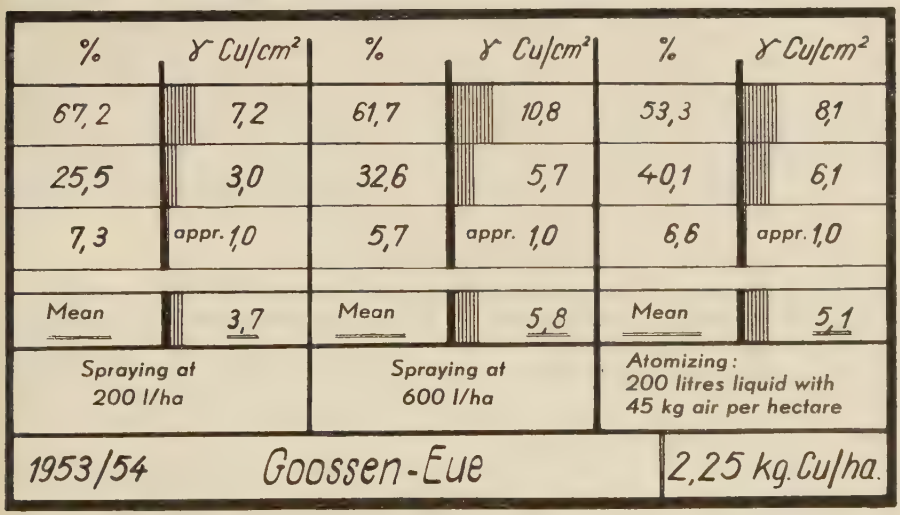


Fig. 3

attributed to this deficiency. This suspicion can be confirmed today, partly by test results and partly by practical experience gained over a period of four years. The "Aero" Boom was used for a practical re-checking of the above-mentioned "compensation thesis", because as far as I know this is the only field apparatus which at present corresponds to this thesis.

The comparison of the summarized means from two tests is intended to illustrate the effect of high quantities of air used as compensation with a great

saving of water (Fig. 3). The tests were carried out by "Stations Fédérales"* and Goossen and Eue**, respectively. In both tests, the Cu deposit in potato stands was measured separately in the top (O), centre (M) and bottom (U) sections of the potato plant, and determined in γ Cu per cm² leaf surface. The illustration gives the average total values for the adaxial and abaxial leaf surfaces. In three of the tests, field sprayers were used applying at the rate of 1000, 600 and 200 litres per hectare, and in two tests field atomizers each applying at the rate of 200 litres per hectare. The two atomizers used differ insofar as the one employed in the Goossen test only discharged approximately 45 kg of air per hectare while the other used in the test conducted by "Stations Fédérales", and which was fitted with the "Aero" Boom, had an output of approximately 1100 kg of air per hectare.

The absolute γ values can only be compared within the two test groups because "Stations Fédérales" distributed 3·75 kg Cu per hectare whereas Goossen distributed only 2·25 kg Cu per hectare. For this reason, the Cu distribution in O, M, U is also given in percentage. The percentage values are all comparable reciprocally.

Distribution of copper (O, M, U) and average copper deposit per cm² leaf:

a) Spraying at 1000 litres per hectare:

Distribution: (O, M, U) very good.
Cu deposit: also good (8·6).

b) Spraying at 600 litres per hectare:

Distribution: (O, M, U) much worse than spraying at 1000 litres per hectare.
Cu deposit: (5·8) relatively ($\frac{5{\cdot}8 \times 3{\cdot}75}{2{\cdot}25} = 9{\cdot}7$) better than at 1000 litres per hectare.

c) Spraying at 200 litres per hectare:

Distribution: (O, M, U) even worse than spraying at 600 litres.
Cu deposit: (3·7) relatively ($\frac{3{\cdot}7 \times 3{\cdot}75}{2{\cdot}25} = 6{\cdot}2$) much less than spraying at 1000 litres and 600 litres.

d) Atomizing at 200 litres with 45 kg air per hectare:

Distribution: better than spraying at 600 litres but considerably worse than spraying at 1000 litres.
Cu deposit: (5·1) less than spraying at 600 litres but when viewed relatively ($\frac{5{\cdot}1 \times 3{\cdot}75}{2{\cdot}25} = 8{\cdot}5$), practically as for spraying at 1000 litres.

e) Atomizing at 200 litres with 1100 kg air per hectare:

Distribution: better than spraying at 1000 litres.
Cu deposit: (15·3) 71 % higher than spraying at 1000 litres. Cu deposit "U" practically doubled compared with spraying at 1000 litres.

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* Dr. M. Staehelin and Dr. G. Trivelli, Stations Fédérales d'essais agricoles, Lausanne: « Les appareils de pulvérisation et leur emploi dans la lutte contre le mildiou de la pomme de terre. » Published: « Revue Romande d'Agriculture, de Viticulture et d'Arboriculture » — No. 5 — 1953.

** Dr. H. Goossen and Dr. L. Eue, Pflanzenschutzamt Münster: „Verteilung, Regenbeständigkeit und Umlagerung von Spritz- und Sprühbelägen im Kartoffelbestand." Höfchen-Briefe 1955, No. 2.

The illustration shows what an important influence the air compensation has on the development of the water-economizing field atomizing method. Consequences of an advantageous nature, however, do not arise only in the control of *Phytophthora*. A most surprising secondary effect was discovered three years ago in the control of weeds with DNC, namely that the cereal plants — treated with "Aero" Booms at the rate of only 300 litres per hectare, with a treble concentration — are harmed to a slighter degree than when they are sprayed at the rate of 1000 litres per hectare, added to which the weed extermination rate is the same. The reason for this is that small droplets are shaken and blown off the grasses by the strongly blowing "wind screen". The "wind screen" of the apparatus has also led to the more or less complete elimination of drifting caused by natural winds. This means that there is practically no longer any danger of neighbouring fields and persons being exposed to drifting 2,4-D droplets or highly toxic clouds of spray mist.

For many years past, the "Aero" Booms have been in use in Switzerland to treat field crops of all types. It is estimated that the "Aero" Booms are used today on approximately 200 farms. With one single exception, namely when killing potato tops by spraying, no more than 400 litres of liquid are applied per hectare. In approximately 80 % of all cases, applications are made at the rate of 200 to 300 litres per hectare. On the other hand, farmers and growers are not recommended to apply at a rate of less than 200 litres per hectare.

The views presented here on the technology of field atomizing by no means constitute new discoveries but merely amount to experience gained with atomizers in fruit growing being applied to agriculture. For some time past, quantities of air have been applied in fruit growing, which in weight are many times larger than the quantities of liquid saved. The application of this atomizing method to agriculture, however, necessitates the development of a completely new apparatus technique.

II. Technique of Atomizing

The field atomizers which were constructed before the technology of atomizing with air compensation was clarified, have a common fault, namely that they distribute far too little air. They do not even give an approximate compensation for the quantities of liquid saved, and therefore they have the following deficiencies:

1. Inadequate wetting of large and dense field stands.
2. Poor resistance to drift.
3. Cannot be used for dusting.
4. Cannot be employed for treating trees.

Deficiencies 1 to 3 appear on a greater scale, increasing proportional to the amount of liquid saved, in the liquid-economizing field sprayers (fitted with economizer nozzles) which operate without air compensation.

Naturally, the above-mentioned technology of atomizing can be put into practice technically from several aspects, at least with full air compensation. These aspects are based on

a) the field atomizer tube itself;
b) the overall conception of the apparatus.

Since 1949, the author first undertook the development of a widely distributing atomizer tube. To operate this tube, several apparatus types had to be specially produced. These were also included in the development work.

The development was completed in five years based on the following main conceptions in respect of the atomizer tube (finally leading to the development of the "Aero" Boom):

1. With respect to the volume, the air is the chief medium to be emitted (liquid to air $\sim$ 1:3000). This medium is intended to produce a strong "wind screen" directed into the plant stand. The liquid droplets are contained in this screen, and are therefore protected against drift.
2. The "wind screen" is formed by a series of closely arranged air jet tubes set pointing into the plant stand.

The emitters are connected to a horizontal distributor tube of large diameter. This tube feeds the compressed air to the emitters. The air flows in at one end of the distributor tube, and is then mixed with the liquid dosed in droplet form in front of the inlet. The task of the compressed air is

a) to cause a uniform break-down of liquid on the emitter;
b) to effect the final atomization of the liquid at the emitter outlets.

This idea provides for

a) the dosing of the liquid to be centralized in one dosage opening common to all emitters. This means that the functions of dosing and atomizing which are combined in the "atomizer nozzle", are separated in the "Aero" Boom;
b) the development, by this means, of an atomizer tube with large flow cross-sections at all points, which can also be used for dusting.

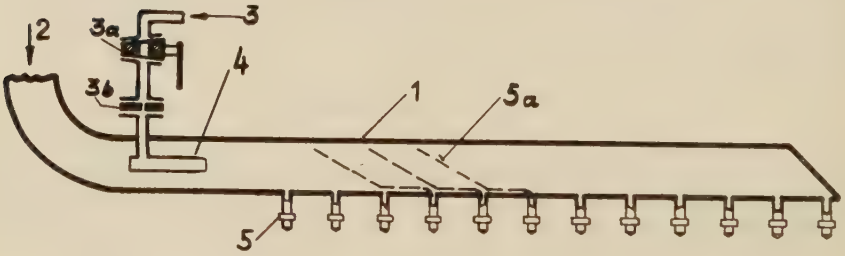

Fig. 4

The construction and operation of the atomizer tube

are shown in Fig. 4. (1) is a sheet-metal tube with a diameter of approximately 13 cm and a length of 4 metres. Two of these tubes arranged horizontally at the left and the right-hand side of the atomizer apparatus, form the "Aero" Boom giving an atomizing width of 8 metres. The compressed air is fed in at arrow (2). It flows through the tube in a longitudinal direction, and is blasted out of 28 emitters (5) at a velocity of 70 m/sec. into the plant stand. There is a spacing of only 14 cm between the emitters, and each emitter discharges 1 m^3 of air per minute. With an atomizing width of 8 metres, we therefore have 56 emitters which together discharge approximately 60 m^3 per minute. The spray liquid is fed in at arrow (3) through an injection device (4) in the axial direction of the boom (1) at a pressure of 1 atm. (centrifugal pump). A part of the air current (2) passes through the injector together with the liquid. At the outlet of the injector,

the liquid is atomized and mixed with the onflowing air. The injector and the flowing air are synchronized in such a manner that the droplets — evenly distributed over the entire length of the tube (1) — are deposited in the form of a film on the inner wall. The liquid film flows downwards, and is at the same time forced in the direction of the air current, giving a component of the flow direction as shown by line (5a). At the base of the tube, a section of the film trickles in the form of a channel (12, Fig. 5) into the next emitter.

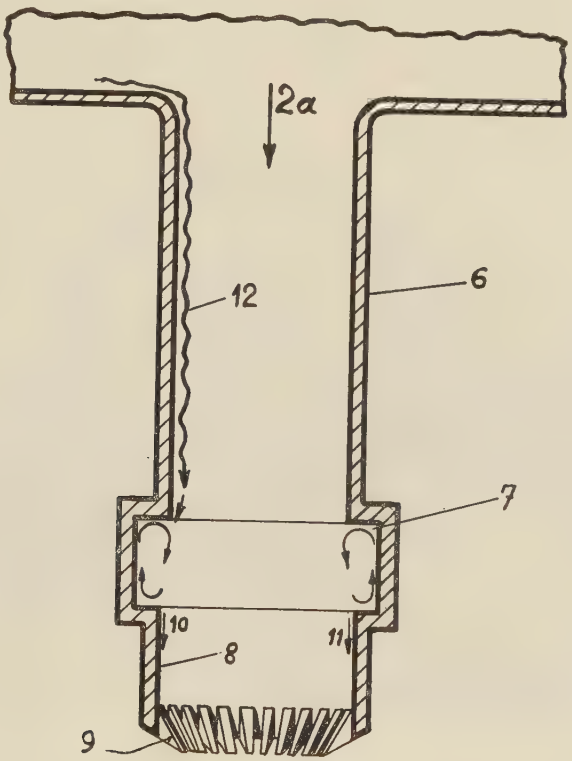

Fig. 5

Therefore, the purpose of this first atomization is merely to distribute the liquid with the aid of the air current evenly inside the boom over the entire length of 4 metres, so that not only air but also liquid of approximately equal quantities is fed to each emitter. Fig. 5 gives a schematic illustration of the longitudinal view of an emitter. It has an internal diameter of 17 mm, given by the quantity of air flowing through, which amounts to approximately 1 m^3/min. The final atomization of the liquid is effected by being fed to the tips of the teeth arranged radially at the outlet where it is then broken down by the air current. It is, therefore, essential that all 26 teeth are equally supplied, i. e. the channel (12) must be fed to the teeth tips in 26 equal channel parts.

This task, too, is completed in a simple manner by the air current which produces a pressure drop in the sudden, ring-shaped widening (7) of the emitter, into which the channel (12) must flow. It is not until the ring chamber (7) is filled with liquid that the "air cylinder" (2a) scrapes off a tubular liquid film of equal thickness from the internal diameter of the liquid ring at (10) and (11). This film then continues to flow downwards in the teeth gaps while the air current forms a new depression at the ridges of the 26 specially designed teeth (9). A 26th part of the liquid collects in each depression. Due to the downward inclination of the teeth ridges, the liquid flows to the teeth tips where it is broken down into droplets by the air current (2a). As a result of this construction, the droplets are produced directly in the air jets which make up the "wind screen", so that they are rendered drift-proof as soon as they are formed.

Fig. 6

The emitter outlets, including the teeth, are made of pressed polyethylene parts, a material which is chemically resistant and elastic. Consequently the teeth are resistant to impact.

With this system, liquid quantities of 100, 200, 300, 400 and 600 litres can be applied by changing the orifice (3b).

The size of the discharged droplet can be determined by the shape given to the tooth in the emitter outlet.

It is not difficult to recognize from the illustrations (Figs. 4 and 5) that the "Aero Boom" can be operated immediately as a duster tube when the liquid cock (3a) is closed and dust is mixed with the air (1) at the blower (Fig. 6). The technological considerations given to the problem as a whole were instrumental in initiating the design of the atomizer and duster tube as the main aim, while

a certain degree of inventive imagination was applied in an endeavour to achieve the following secondary aims:

a) Preclusion of atomizer nozzles thus eliminating the problem of nozzle stoppages.

b) Replacement of the plunger pump by the centrifugal pump.

c) Employment of the one tube for both atomizing and dusting.

The advantages of this solution are countered by the disadvantage that the boom tube, for aerodynamic reasons, must be made in one piece which cannot be sub-divided in its length. With an atomizing width of 8 metres, two rigid boom tubes each 4 metres long must be handled, which are heavier than the standard type nozzle booms. This disadvantage, however, was overcome by the constructional design of the entire apparatus.

It has already been mentioned that small units with boom lengths of 6 and 7 metres were first tested. This work was followed by the development of a large apparatus based on the following factors:

a) Pest control work with chemicals is gradually passing into the hands of trained personnel, employed either by sub-contractors, amalgamations of different forms of organizations or large-scale farmers who mostly carry out this work under their own supervision and with their own machines. In Europe they require apparatus operating on a greater economical basis, which can also be employed for many purposes in agriculture, fruit growing and forestry.

b) Today tractors and "Unimog" type trucks are available everywhere, which are fitted with power take-off shafts so that they can be used for operating pest control machines.

The atomizing and dusting apparatus designed for power take-off drive to be operated by tractors was given the designation "T"-8 ("T" = tractor, and "8" means 8 metre boom length). It is manufactured as a trailer and as a mountable apparatus for operation with tractors, and also as a special apparatus for mounting on the platform of the "Unimog" truck. The mountable

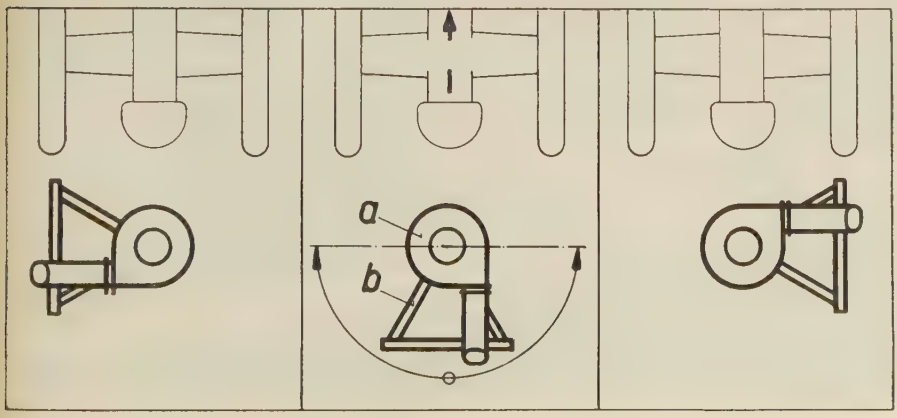

Fig. 7

Fig. 8

Fig. 9

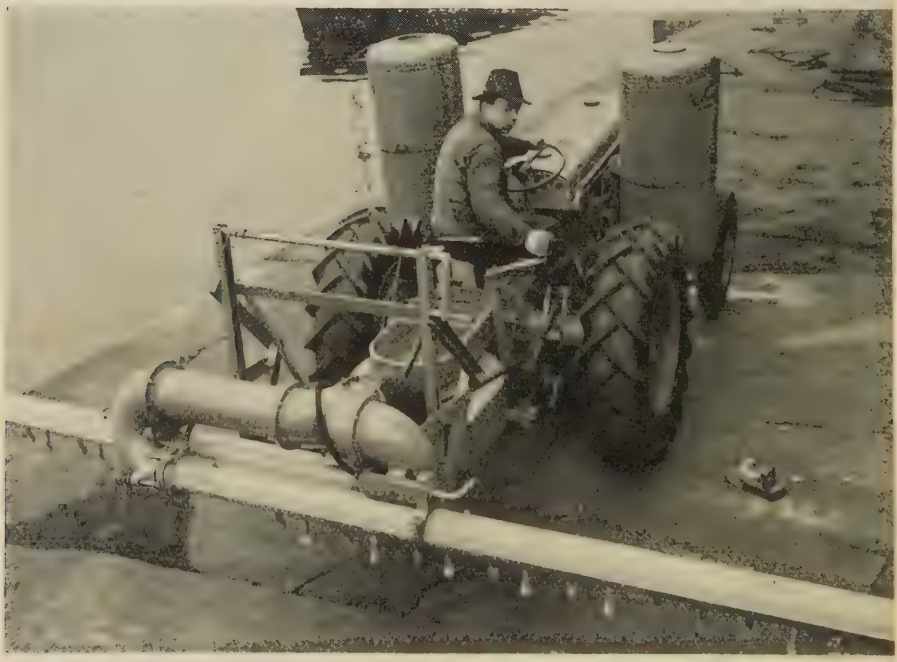

Fig. 10

apparatus is of advantage when it is to be used continuously for long periods (sub-contractors, associations), whereas the trailer permits quick coupling and uncoupling, an advantage to farmers who have to switch the tractor from one job to another very quickly — for example when rainy weather suddenly sets in.

The rigid "Aero" Boom requires a horizontally located blower (axle vertical). The housing of the blower, air connection to the boom, and the boom itself must swivel around the vertical blower axle. As a result of this, the driver can turn the boom from the working position so that it is in the driving direction alongside the vehicle without having to disconnect any unions. For this reason the blower (a, Fig. 7) is firmly connected to a platform (b), and they can be swivelled together through 90 ° to the left and to the right. For field treatment, the boom is mounted on the platform (b) whereas for single tree treatment a

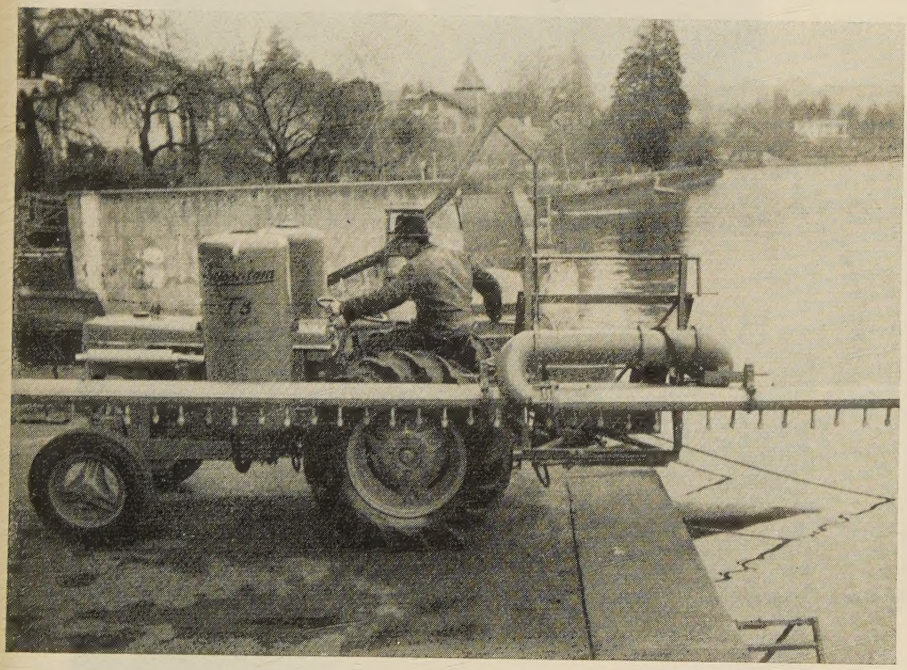

Fig. 11

seat is fitted on the platform for a second operator who works the aiming tube. He does this by operating a handle — again making use of the traverse principle — which turns him, the platform, the blower and the aiming tube in the direction he wishes to aim the spray, while he moves the aiming tube vertically with the other hand (Figs. 8—11).

A centrifugal pump located on the blower axle which is extended downwards, boosts the liquid at a pressure of 1 atm. It is also used for filling the wash tank, and for agitating the wash. This is effected by backstreaming at the rate of 50 to 60 litres per minute.

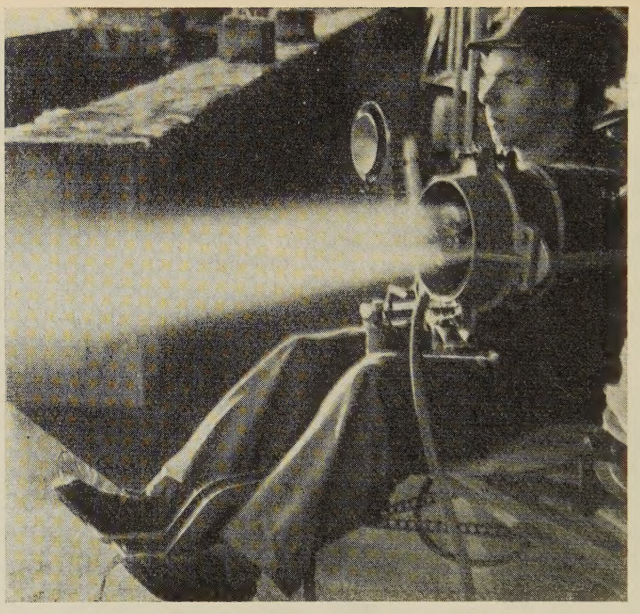

Fig. 12

Fig. 13

An intersting feature is a new, swivelling wide-jet orifice for close-up treatment fitted to the outlet of the aiming tube for tree treatment. It damps the spray jet by drawing out the jet as it leaves the outlet to form a wide cone with a larger emitting surface (Figs. 12 and 13).

III. Quality and Economy

Reference has been made to the decisive influence the technological process has on the quality and the economy of the field treatment.

The quality factor always receives its final confirmation from the practical effect although studies on the distribution of active substance and the deposit quotas can provide extremely valuable information as to the quality of the treatment. Whenever such studies are conducted, the distribution and the deposit quota should be shown in relation to each other in such a manner that the general assessment automatically becomes obvious.

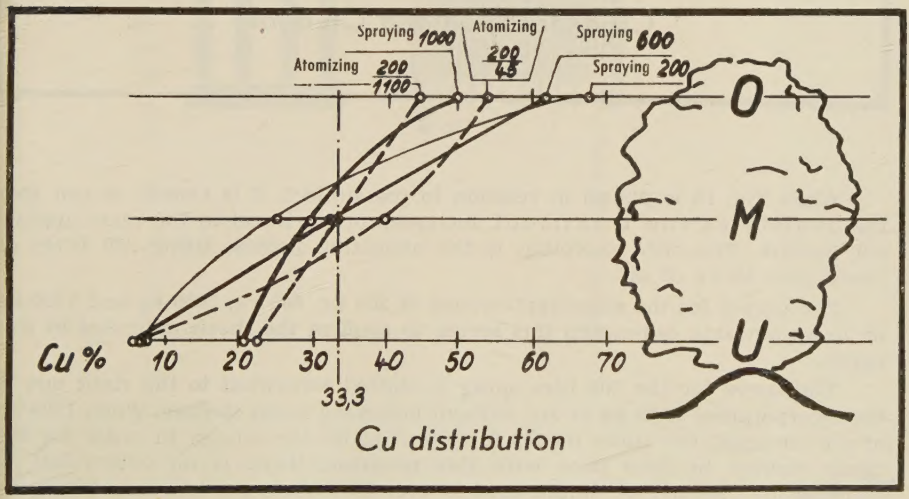

Fig. 14

By way of example, Fig. 14 shows as a graph the figures obtained for the percentage Cu distribution in each process illustrated in Fig. 3. The process with the distribution curve deviating least from the vertical (= 33·3 %), gives the best distribution. In Fig. 15, the curves from Fig. 14 are arranged on the quota scale. Each curve starts at the top at the particular quota figure which was calculated as the "mean" for the respective process in Fig. 3. Fig. 15 gives a clear comparison of the "quality" of our five processes. The most favourable curve is the one which runs steepest and farthest to the right. If there are no points of intersection with other curves, then the assessment is especially clear. This reflection of quality does not include drift which must be assessed separately.

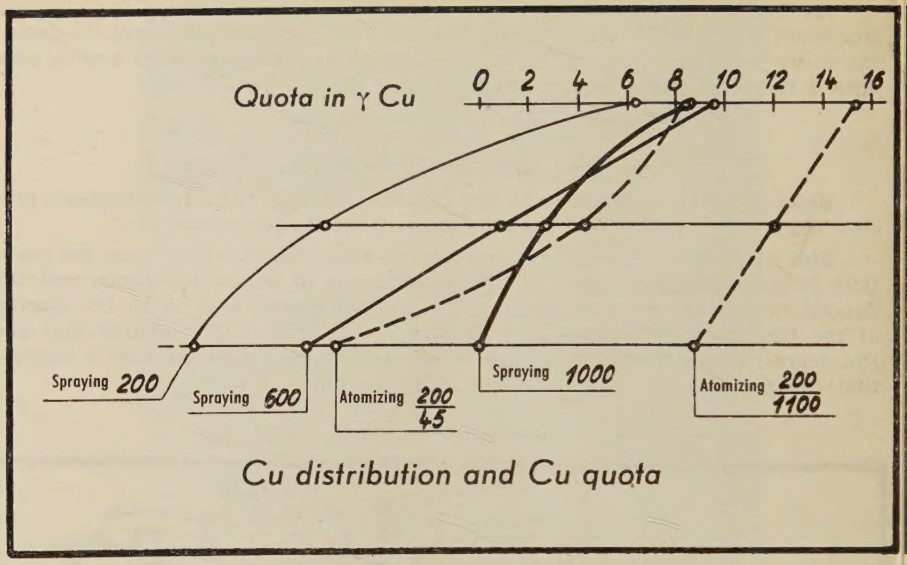

Fig. 15

When Fig. 15 is placed in relation to the subject, it is clearly shown that the quality of the treatment increases proportional to the mass applied per hectare. The only exception is the atomizing process using 200 litres of liquid plus 45 kg of air.

The curves for the mass applications of 200 kg, 600 kg, 1000 kg and 1300 kg lie in an amazing order, and this serves to confirm the thesis defended in this paper.

The curve for the 200 litre spray is shifted somewhat to the right due to the incorporation of 45 kg of air, without becoming much steeper. When 1100 kg of air are used, the curve moves far ahead of all the others. In order for the spray method to keep pace with this progress, there is no option but to increase the quantity of liquid used to over 1000 litres per hectare accompanied by an increase in pressure to approximately 60 atm. at the nozzles. At this stage, however, the economy factor enters into discussion, but it is generally known that this can only be favourably influenced to a large degree by cutting down the quantity of water used. Therefore, if from this aspect a top limit for water consumption of 300 litres (maximum of 400 litres) per hectare is desired, it can only be attained by developing the method of application to give a higher standard of quality. The atomizing method offers the only future prospects for wet application.